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Integration of Architecture for Behavior and Cognitive Modeling (ABCM) with the Joint Conflict and Tactical Simulation (JCATS)

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Interim Report for March 2002 – April 2003

Air Force Research Laboratory
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FOR THE DIRECTOR

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14. ABSTRACT

This report describes the effort to demonstrate the flexibility of CACI's Architecture for Behavior and Cognitive Modeling (ABCM) to incorporate and alternate between psychological models. For this project, the models were based on work in CACI's FY02 Asymmetric Warfare (AW) project. This report also describes the development of a formal process to use Subject Matter Experts (SMEs) in the Knowledge Acquisition (KA) and Verification and Validation (V&V) for a model using a fuzzy rule set Knowledge Base (KB). This plan and process was used to support the development of a more complete commander's model in the Agent-based Modeling and Behavior Representation (AMBR) program. The development involved the design, implementation, and testing of a significant larger, more complete KB, containing a total of 180-200 fuzzy rules. CACI developed two interchangeable psychological rule sets and a cultural and rudimentary socio-political rule set to influence the commander traits. A Graphical User Interface (GUI) was developed to build, analyze, and test the modularity of the psychological rule sets.

15. SUBJECT TERMS Human Behavior Modeling, Architecture for Behavior and Cognitive Modeling (ABCM), Joint Combat and Tactical Simulation (JCATS), Fuzzy Rule Sets, Rule Set Collaboration, Knowledge Acquisition

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PROBLEM

The Defense Modeling and Simulation Office (DMSO) requested that the CACI Team demonstrate the flexibility of the Architecture for Behavior and Cognitive Modeling (ABCM) to incorporate and alternate psychological models. According to the Statement of Work (SOW) for Integration of ABCM with Joint Combat and Tactical Simulation (JCATS), Revision 2, 27 January 2003, the revised models shall be based on work that began in the FY02 Asymmetric Warfare (AW) project, and shall be demonstrated using an agreed-upon runtime framework.

In addition, DMSO requested for the development of a plan that describes a formal process to use Subject Matter Experts (SMEs) in the Knowledge Acquisition (KA) and Verification and Validation (V&V) efforts for the development of a more complete commander's model with fuzzy rule set or Knowledge Base (KB). According to the SOW, this plan shall leverage KB work that began under the FY02 AW project, especially rule sets on cultural influences and psychological influences, where appropriate.

OBJECTIVE

The objective of this research was to support the development of a more complete commander's KB model in the Agent-based Modeling and Behavior Representation (AMBR) program. This involves the design, implementation, and testing of a significantly larger, more complete fuzzy rule set or KB, containing a total of 180-200 fuzzy rules.

APPROACH

Based on the rule sets KA and rule sets development effort under the AW project, the CACI Team developed two interchangeable psychological rule sets and a cultural and rudimentary socio-political rule sets to influence the commander trait. A Graphical User Interface (GUI) was developed to build, analyze each rule set, and test the modularity of the psychological rule sets.

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1 INTRODUCTION

This interim report is a required deliverable under the SOW for Integration of ABCM with JCATS, Revision 2, 27 January 2003. This report documents the work performed on this JCATS project, as modified in the SOW, to include the subset of the FY02 AW project tasks that are directly supporting or related to this project's tasks.

1.1 BACKGROUND

The integration of ABCM with JCATS was originally intended as a proof-of-principle demonstrating the reuse and application of advanced Human Behavior Representation (HBR) technologies to support real world Military Operations in Urban Terrain (MOUT) small-unit course-of-action analyses and mission rehearsal operations using the JCATS. The SOW was modified to benefit the anticipated commander's model upgrades for the AMBR program.

1.2 ORGANIZATION OF THE REPORT

This report is divided into four sections as described in the following table.

Section	Section Description
Section 1	Provides an introduction of this document.
Section 2	Describes the AW project's tasks that support the effort reported in this document.
Section 3	Documents the work involved in the modular rule set demonstration.
Section 4	Documents the work involved in the preparation of the detailed plan for the development of a more complete commander's model KB.

2 FY-02 AW Program Supporting Tasks

This Section describes the subset of the FY02 AW project tasks that are directly supporting or related to the effort described in this report. These tasks are described in detail in the AW Phase I Final Report, dated January 2003. The final report was presented to DMSO on March 4, 2003.

2.1 Rule Sets KA

The CACI Team assessed three personality inventories (Myers-Briggs Type Indicator (MBTI), Minnesota Multiphasic Personality Inventory, and NEO-Personality Inventory-Revised (NEO-PI-R)) against the needs of modeling an unknown enemy (e.g., one who has not taken a personality test). The personality rule set KA focused on establishing the best personality testing approach. The conclusion was that the NEO-PI-R features make it a good basis for describing the behaviors of individuals whom the modeler does not have the luxury of testing. The high inter-rater reliability suggests a rule-set based on NEO-PI-R can be independently validated.

The cultural rule set KA had two goals: 1) establish broad categories that cross cultures, and 2) understand the cultures specific to the scenario. The conclusion was that cultural rule-set adequately supports the goals of exploring how two disparate influences on individual's decision-making might be provided to a simulation-based training exercise. However, it suffers from an insufficient basis in an excepted sociological model to allow for independent validation.

The socio-political rule set KA focused on broad concerns of economic conditions and education.

Allowing rule-set collaboration only at the end of the chaining simplifies the analysis and is a therefore a logical first step in exploring collaboration. It also supports the use of alternate rule sets whose designers need only know about the end facts in the chaining. The use of an "OR" relationship is logically consistent with providing a build-up of tendency among the separate influences in an individual's decision process.

2.2 Rule Sets Development

The CACI Team designed three fuzzy KBs, as described below:

- A psychology rule set based on the NEO-PI-R.
- A cultural rule set representing three cultural subsets.
- A rudimentary socio-political rule set.

The design for these rule sets allowed them to collaborate through common final facts. In addition, the rule sets were designed for plug-and-play, where most inputs to these rule sets are determined by the user. Finally, these rule sets influence the risk/reward utility function in the agent (commander) planning.

2.3 Inference Engine Development

The existing ABCM fuzzy rule set inference engine was modified and used to establish the design parameters for the rule sets. This inference engine supports single rule set operations and collaborating rule sets operations.

In single rule set operations, each of the rule sets consists of a set of fuzzy facts. Associated with each fact is a list of fuzzy rules that help to establish that fact. Each rule associates the fact with a particular membership function. Rules that associate the fact with a common membership function are executed through an algebraic OR. The algebraic AND is only employed when two phrases of a rule are ANDed. If two conditions are to equally contribute to a facts value, they are represented by separate rules. In such a way, the inference engine will perform the OR. In collaborating rule sets, rules that establish the same fact in the same membership function are executed through an algebraic OR. As long as more than one rule set does not employ the rule names, their rules will never collide Collaboration between the two rule sets is controlled through the choice of fact name. For this initial exploration of cultural and psychological interplay, that collaboration was limited to the final facts. Each rule sets produces the same eight final facts. Thus, each rule set is able to consider the set-up data and the situational data provided by the simulation test bed within which it is hosted, to independently or cooperatively assess the agent's likelihood to behave in a particular manner.

2.4 GUI Development

A GUI was developed to build and test the rule sets based on the user inputs. This GUI allows an analyst to do sensitivity testing before attaching the knowledge base to its simulation test bed. The analyst can select one rule set to work independently or several to work cooperatively. The GUI displays the total number of facts, rules, and membership functions, and breaks the facts into four categories: 1) the input facts to be set by the user, 2) the input facts derived by an associated algorithm, as used for the NEO-PI-R and MBTI rule sets, 3) the intermediate facts whose value is set by rules, but which do not represent the final answers, and 4) the final answers which are set by rules.

3 Modular Rule Set Demonstration

This modular rule set demonstration effort consisted of implementing interchangeable rule sets representing the NEO-PI-R and MBTI personality models, and demonstrating modularity and flexibility of the rule sets. This effort included the development of a cultural and a socio-political rule sets to demonstrate value added.

3.1 Technical Requirements

The NEO-PI-R and MBTI personality rule sets shall be moderately equivalent in quality. In addition, they shall be integrated with the related cultural and socio-political rule sets developed under the DMSO AW program. Refer to the AW Phase I Final Report prepared for the Naval Air Systems Command Naval Air Warfare Center Training Systems Division under contract number N61339-02-C-0084, dated January 2003.

3.2 Preparation for the Demonstration

The process for developing the interchangeable rule sets and preparing the modular rule set demonstration consisted on three major tasks: design and development of a GUI, implementation of the rule sets, and testing of modularity and integration of the rules. These tasks are described in detail in the following subsections.

3.2.1 Development of Modular Rule Set GUI

The CACI Team upgraded the GUI developed under the DMSO AW project to support the modular rule set demonstration. This effort consisted of:

- Building rule sets input mechanism
- Updating the rule tester
- Updating the rule sets visualization

The CACI Team developed an input GUI to build the MBTI and NEO-PI-R rule sets. Figure 3-1 shows the screen for the input GUI for the MBTI rule set.

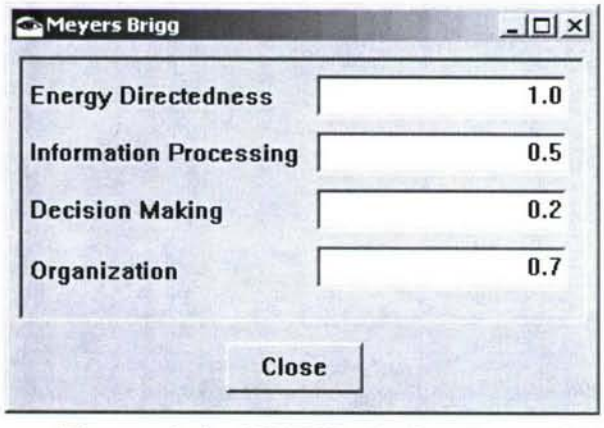

Figure 3-1. MBTI Rule Set Input GUI

Figure 3-2 shows the input GUI screen for the NEO-PI-R.

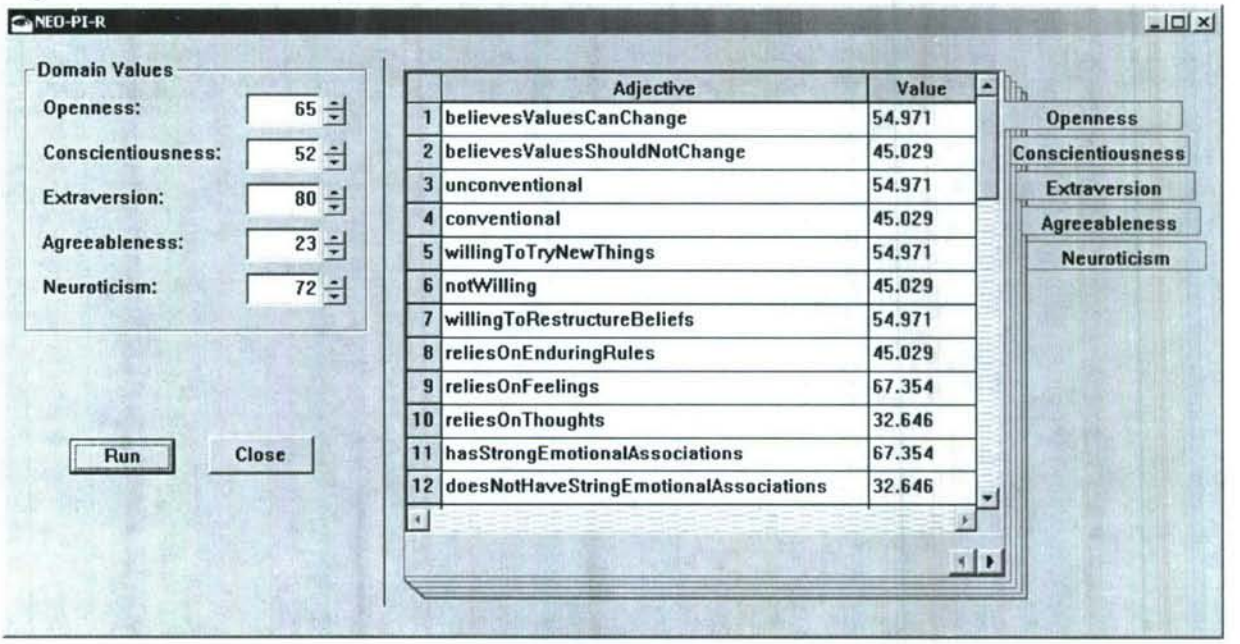

Figure 3-2. NEO-PI-R Rule Set Input GUI

To test and demonstrate the modularity of these two psychological rule sets, the GUI shown in Figure 3-3 was developed.

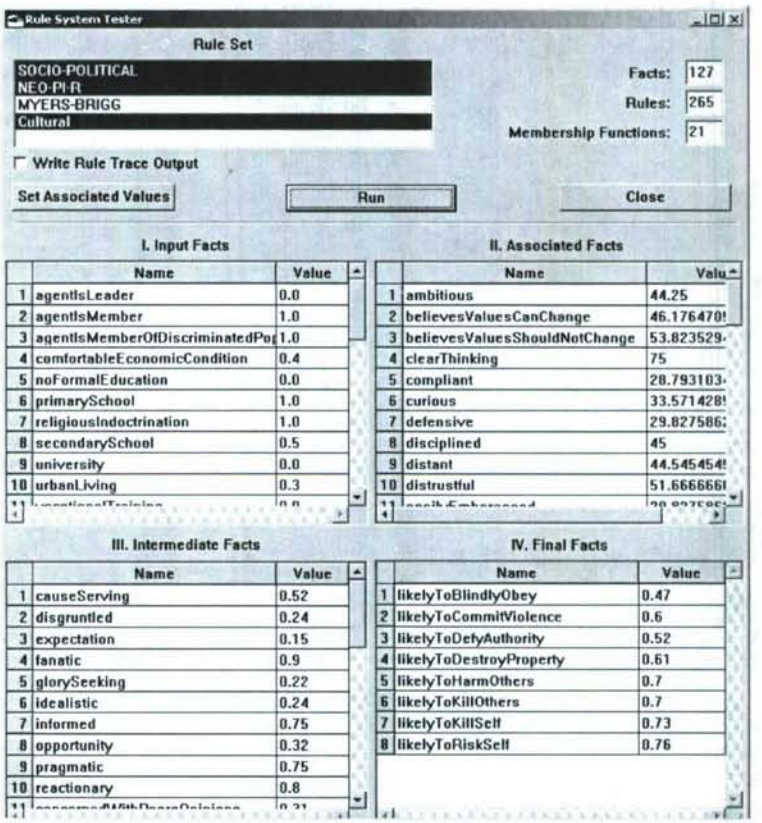

Figure 3-3. Rule Set Tester GUI

In addition to the tester GUI illustrated in Figure 3-3, the CACI Team developed a visualization tool to graphically show the rule sets collaboration and navigate through the facts. This tool was developed using the Graphic Framework for SmallTalk (GF/ST) software. An example of this visualization tool's capabilities is shown in Figure 3-4.

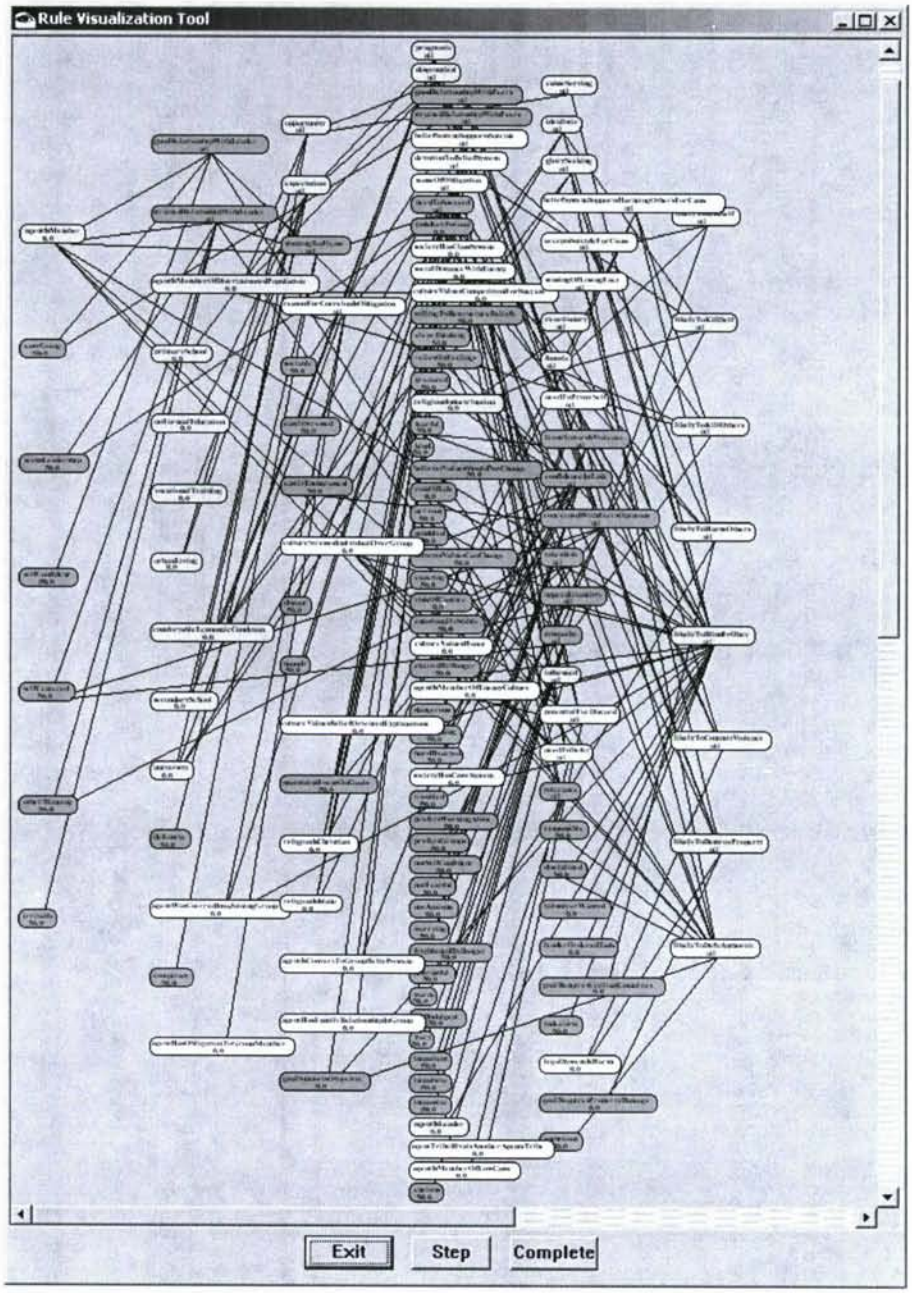

Figure 3-4. Rule Sets Visualization Tool

3.2.2 Inference Engine Updates

The existing inference engine used in the DMSO AW project was updated to support the modularity of rule sets. When a fact is added to a rule set, the inference engine checks to see if the fact already exists in the rule set; and if it does, all of the rules of the new version of the fact are added to the rules of the old version of the fact to create a new fact.

3.2.3 Development of Modular Rule Sets

The CACI Team implemented the NEO-PI-R, socio-political and cultural DMSO AW rule sets. The MBTI rule set was developed specifically for the modular rule set demonstration to have two interchangeable psychological rule sets. This effort consisted of building the rule sets through the input GUI.

The design and development of modular rule sets is not complete without analysis. The analysis process is essential in the completion process of rule sets. The analysis is vital in developing a complete and accurate rule set, based on the information provided.

3.2.3.1 Analyzing Individual Rule Sets

Very limited analysis was performed for each rule set. Primarily the analysis focused on ensuring that all rule sets contribute to the same final facts, and that "interplay" between rule sets occurs at the final facts.

3.2.3.1.1 Understanding the conditions

All rule sets have different criteria and values associated with a specific set, as listed below.

Assumptions

Each rule set contains different assumptions. For example, the MBTI rule set contains the following assumptions:

1. This rule set is used as part of the description of an n-man terrorist cell.
2. There is one level of hierarchy. That is, there is a leader and other members of the cell are expected to have a peer relationship.
3. The MBTI measures of Energy Directedness, Information Processing, Decision Making and Organization are not the results of a test, but rather a description of a personality provided by a user.
4. Further, the MBTI rules below are mapped to the NEO-PI-R rule set produced earlier. **This does not represent a valid rule set for the MBTI on its own, but rather a mapping to the NEO-PI-R using MBTI descriptors.**

The assumptions are to provide information for the analyst/user.

User Set Up Data

The information given about the specific rule sets allows the user to input values accordingly. For example, the user must choose either AgentIsLeader or AgentIsMember (both can not be used). Boolean values are values that are either 0 or 1. The value 0 and 1 are false and true, respectively. Fuzzy values, however, can be anywhere from 0 to 1 unless otherwise noted.

Membership Functions

The membership functions are created in every rule set. The shape of the membership functions may vary. In this case, the repetitive membership functions include true, false, low, and high which are represented by right and left trapezoids.

3.2.3.1.2 Validating Rule Sets

The analyst checks every output value to ensure that it makes sense. For example, in the socio-political rule set, if an agentIsMember, comfortableEconomicCondition is low, and there is noFormalEducation, the expectation would be a low number. If expectation is a high number, there is a problem in the rule set.

When analyzing rule sets, specific output values can alert the analyst if the rule set is not correct.

Nil Values

The appearance of nil values in the output is not a good indication. There should be no nil values in the output. Nil values could mean that the rule set is not complete. To correct this error, the analyst threads back through the rule set until the problem is found.

Likely values over 0.5

Likely values are not to be too far over 0.5; however, there are some exceptions to that rule. Threading back to the rule is a necessary procedure to analyzing rule sets. If there are likely values over 0.5, the analyst further investigates the rule to determine if it makes sense. If it does not make sense, the analyst modifies the rule to get the correct value.

3.2.3.2 Analyzing Combined Rule Sets

Once the analysis of each individual rule set has been completed, the analysis of the combination of rule sets may be started. The analyst tests as many rule sets as necessary. However, it is not recommended that the user test the NEO-PI-R and the MEYERS-BRIGG rule set together because they depict different personality types.

3.2.4 Test of Modularity and Integration

The CACI Team used the tester GUI to make sure that the NEO-PI-R rule sets can be integrated and interchanged, with or without the cultural and socio-political rule sets influence. The tests conducted by the CACI Team consisted of:

- Execution of NEO-PI-R rule set stand alone.
- Execution of MBTI rule set stand alone.
- Execution of each psychological rule set in combination with cultural rule set, or socio-political rule set, or both.

Each rule set should be individually tested, before a combination of rule sets are tested. This is to ensure that each rule set is accurate before combined testing is executed.

The Rule Tester GUI was used to obtain and test the results from the rules. As the example shown in Figure 3-3, the highlighted rules are the ones that are being tested. With this GUI, more than one rule set can be tested at one time. The Input Facts are facts in which the user inputs values. After the analyst inputs values into Input Facts, the run button is pressed. Intermediate Facts and Final Facts are shown, which are the output values for the specific rule set being tested. The NEO-PI-R and the MBTI rule sets have associated set of values, as shown in Figure 3-5.

Figure 3-5. MBTI Associated Values

While testing these specific rule sets, the analyst inputs these values by pressing the Set Associated Values button, these values will pop up in the Associated Facts section of the GUI.

3.3 Rule Set Measures

This Section summarizes the measures for the four rule sets developed under this effort.

3.3.1 NEO-PI-R Rule Set Measures

Number of Facts:

- Input: 12
- Associated: 49
- Intermediate: 13
- Final: 8
- Total: 82

Number of Rules: 160

Membership Functions: 17

Hedges: 3

3.3.2 MBTI Rule Set Measures

Number of Facts:

- Input: 15
- Associated: 4
- Intermediate: 11
- Final: 8
- Total: 36

Number of Rules: 138

Membership Functions: 39

Hedges: 3

3.3.3 Cultural Rule Set Measures

Number of Facts:

- Input: 19
- Intermediate: 10
- Final: 8
- Total: 37

Number of Rules: 57

Membership Functions: 7

Hedges: 2

3.3.4 Socio-Political Rule Set Measures

Number of Facts:

- Input: 11
- Intermediate: 10

- Final: 8
- Total: 29

Number of Rules: 48

Membership Functions: 14

Hedges: 3

4 Scalability and SME Usage Plan

The CACI Team developed a detailed plan that will enable the AMBR project to provide for more sophisticated, complete, and well-tested ABCM instances. The goal of this project is to incorporate a complex decision-making process within AMBR. The objective is to design, implement and test multiple ABCM instances that support the air planning domain, focusing on the modeling of three decisions aspects of the course of air planning: Apportionment, Air Superiority Levels, and Risk Assessment. This involves building more complete fuzzy rule sets or KBs, with the restriction that a scalability test must be done in at least one of the instances to have a rule set with 180 - 200 rules.

This plan will support these goal and objective with a more formal Air Planning Domain KA approach, an effective use of SMEs and resources for the V&V effort, and an approach for a more comprehensive scalability assessment of the rule sets to be implemented.

4.1 Preparation of the Plan

The Draft plan was prepared and presented to the Air Force Research Laboratory (AFRL) Program Manager and the DMSO Program Manager on March 4, 2003. Based on the feedback from this presentation, a final version of the plan was developed with additional details

4.2 Final Plan

The final plan, Scalability and SME Usage Plan, describes a detailed plan for the AMBR ABCM effort. It presents the rationale and approach for SME-based KA and V&V efforts supporting the development of a more complete commander's decision-making model. In addition, it presents a detailed plan for the design, implementation and test of a significantly larger, more complete fuzzy rule set or Knowledge Base.

APPENDIX A – ACRONYMS

ABCM	Architecture for Behavior and Cognitive Modeling
AFRL	Air Force Research Laboratory
AMBR	Agent-based Modeling and Behavior Representation
AW	Asymmetric Warfare
DMSO	Defense Modeling and Simulation Office
FY	Fiscal Year
GF/ST	Graphic Framework for SmallTalk
GUI	Graphical User Interface
HBR	Human Behavior Representation
JCATS	Joint Conflict and Tactical Simulation
KA	Knowledge Acquisition
KB	Knowledge Base
MBTI	Myers-Briggs Type Indicator
MOUT	Military Operations in Urban Terrain
NEO-PI-R	Negative Emotionality, Extraversion, Openness – Personality Inventory - Revised
SME	Subject Matter Expert
SOW	Statement of Work
V&V	Verification and Validation